SMD User's Guide

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The Solenoid Magnet Designer (SMD) is a Windows program for designing solenoid magnets. The program displays the coil configuration graphically, shows the magnetic field on-axis and shows the net forces on each coil. It also shows the location of the peak field and peak hoop stress in the coils. The current density in the coils is compared with the critical current for the given peak field in each coil. It can also display the force distribution inside the coils, a grid of the off-axis magnetic field, magnetic lines of force, or the Fourier components of the on-axis field. It also contains a built-in optimizer.

1. Starting the program

The program can be started from a DOS (command) window using the command

C:> smd

or

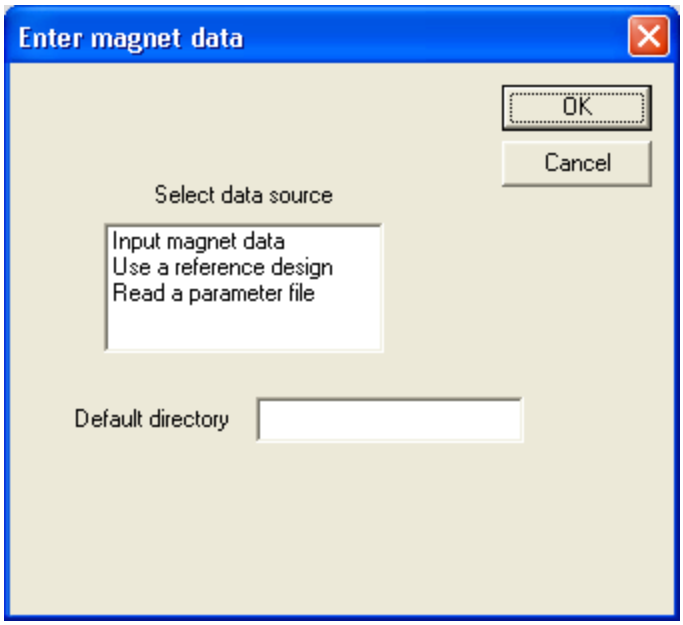
C:> smd file.prm

where *file.prm* is the name of an existing parameter file.

The program can also be started by clicking on its Windows icon.

2. Opening screens

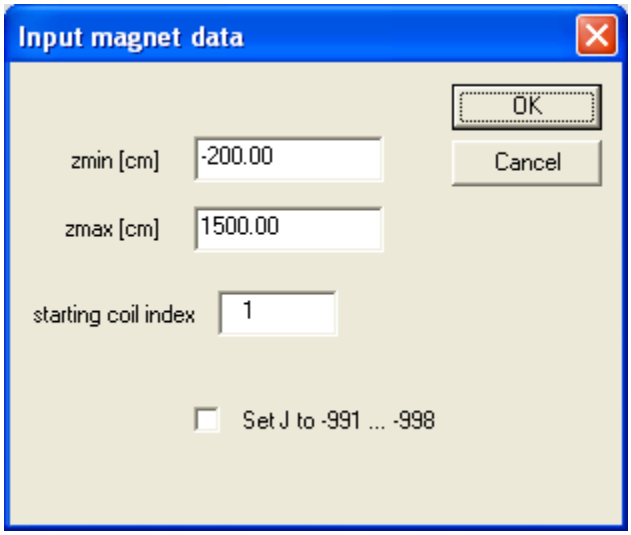
The figure shows the opening screen when the program is started without specifying a pre-existing parameter file.



The user has three choices to enter the magnet design data. The first choice allows inputting the data by filling out a set of dialog windows. The second choice brings up a list of built-in reference designs. The last choice is to read in an existing parameter file that has been previously saved or created offline. The directory for reading and writing files may also be changed here.

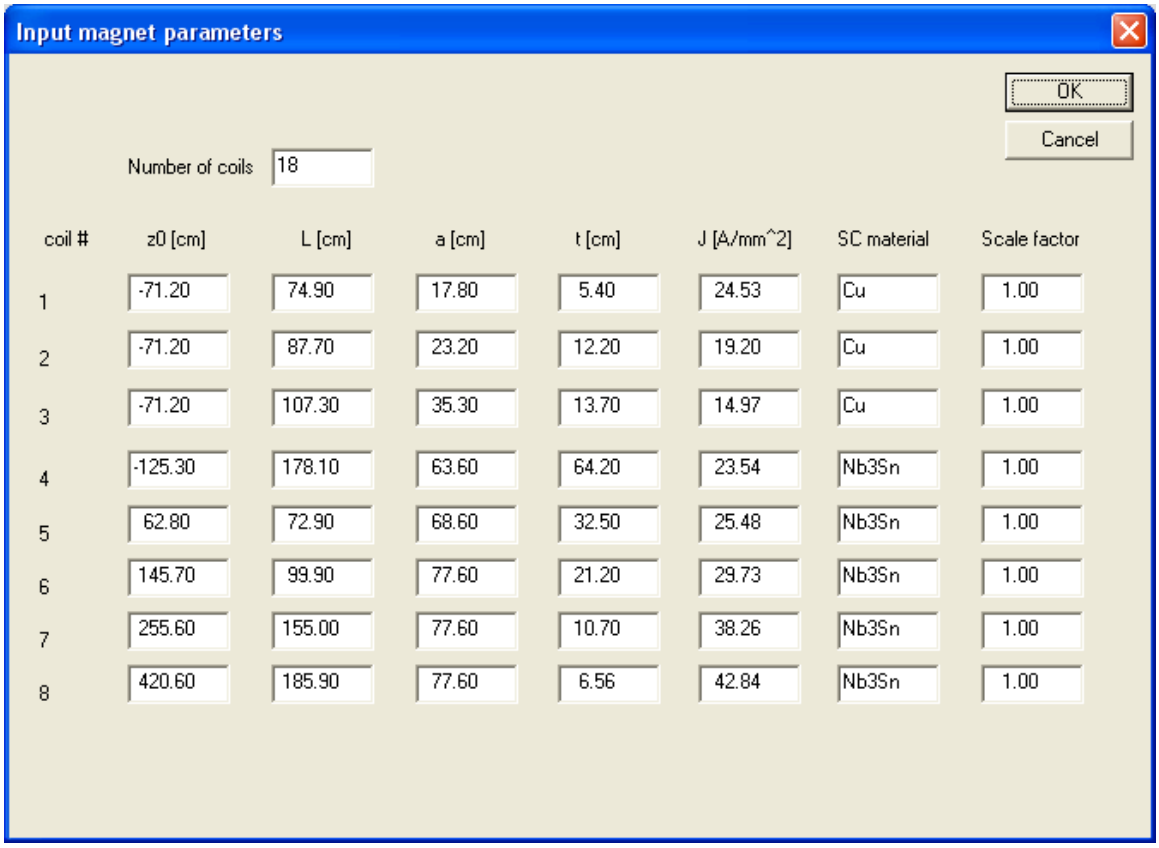
2.1 Entering data using the dialog windows

If the user chooses to input the data by hand, it brings up the window



The quantities *zmin* and *zmax* are the axial limits for field calculations. The following dialog windows only allow changing parameters for 8 coils at a time. However, the starting coil index for 8 consecutive coils can be changed here. The check box at the bottom is used with the optimizer. If the box is checked, the current densities of the eight displayed coils are automatically chosen as the parameters to be varied. This can save some effort during the initial stages of optimization.

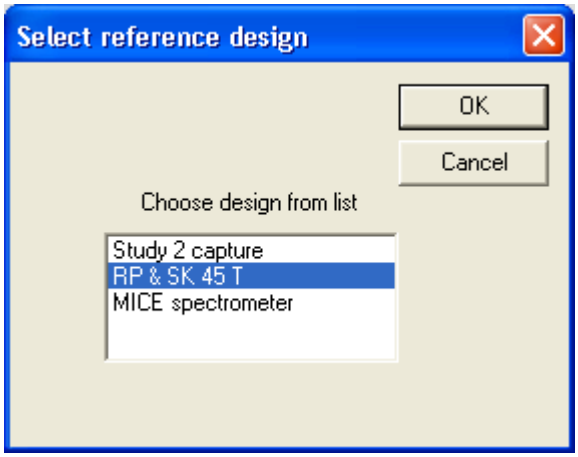
This is followed by a window to enter the coil parameters.



The user sets the number of active coils in the box at the top. Then for each coil the user sets the starting axial position *z0*, the axial length *L*, the inner radius *a*, the radial thickness *t*, the engineering current density *J*, and the type of conductor. The last column is a current density scaling factor that multiplies the critical current for the material. The recognized superconductors are described in section 4. Up to 32 coils may be used in a design, but only the parameters of 8 coils at a time may be changed online.

2.2 Entering a reference design

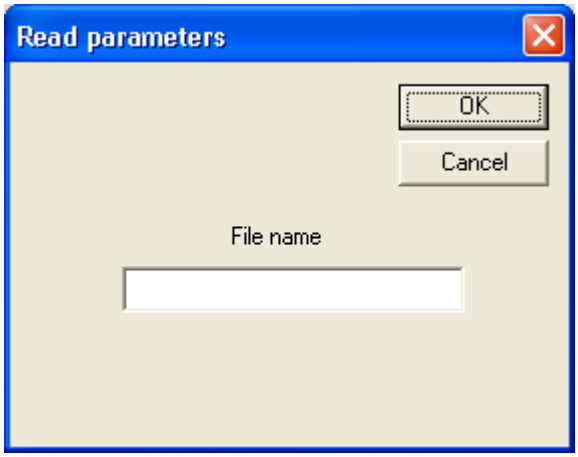
If the user chooses to enter a reference design it brings up the window.



The user should click on an item in the list.

2.3 Entering a saved design

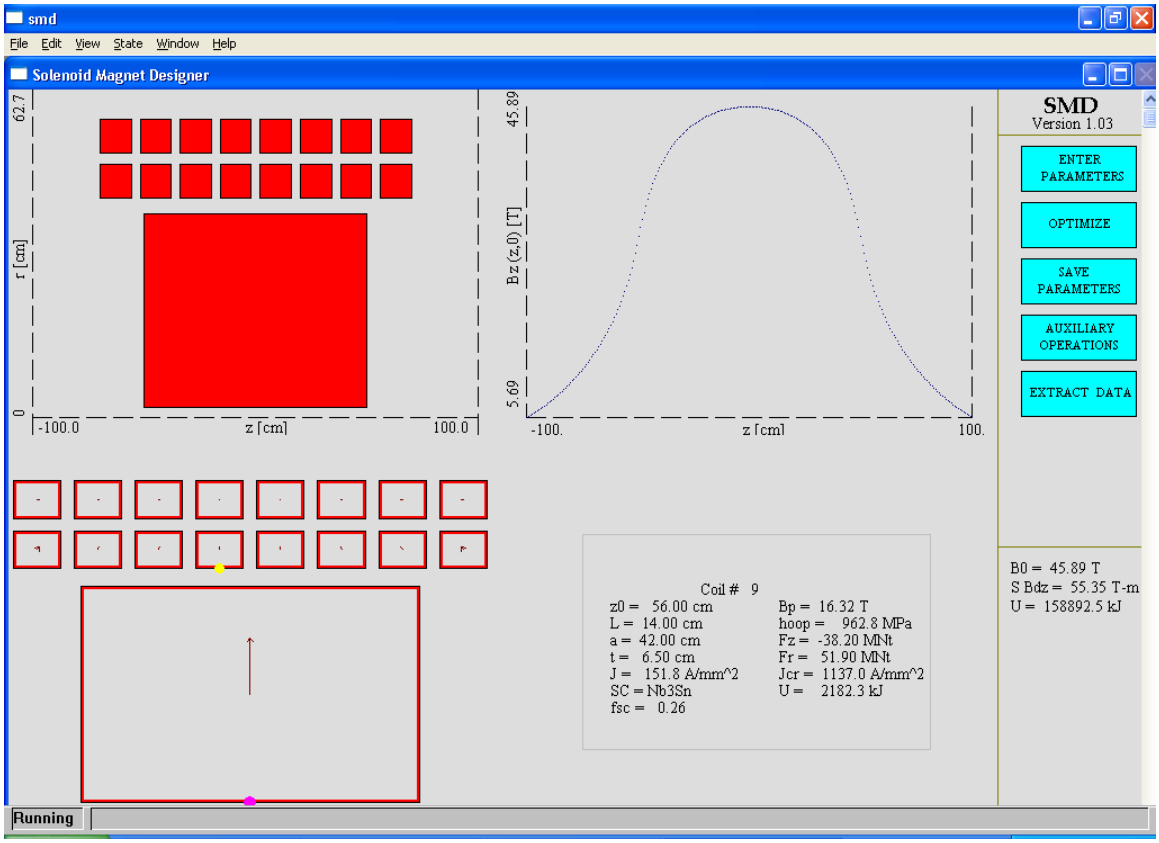
If the user chooses to enter a saved design it brings up the window.



The user should enter the filename of a previously saved design.

3. Results screen

After a design has been entered the program displays a screen similar to the following.



The upper-left graph shows the coil geometry. Coils with positive current are shown in red, while coils with negative current are shown in blue. Unfilled coils with black borders have 0 current, i.e. are turned off. The upper right graph shows the solenoidal field on-axis. The lower left graph shows a blow-up of the coils with the net force indicated on each coil. The magenta circle on the coil shows the peak field location. The yellow circle shows the location in the coils of the maximum hoop stress. Holding the mouse temporarily over a coil in the bottom-left plot will display its properties in the lower right-hand part of the screen. The stored energy refers to the magnetic energy inside the conductor cross section only.

The five buttons on the upper right part of the screen are controlled by clicking with the mouse. ENTER PARAMETERS brings up a series of windows for the user to enter the parameters for a new design. OPTIMIZE brings up a series of windows for the user to start an optimization study. SAVE PARAMETERS is used to save the parameters for a design to a file. AUXILIARY OPERATIONS brings up a choice of additional calculations. EXTRACT DATA creates external ascii files of selected information.

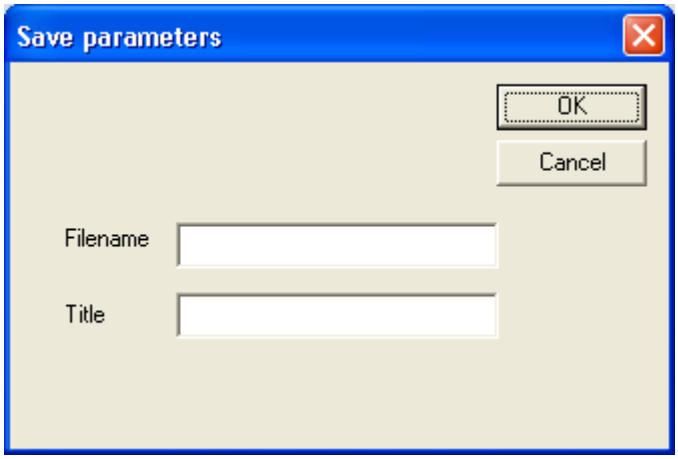
The area on the lower right is used to display numerical values for some important coil properties.

The magnet characteristics given in the lower right hand box are:

B0	maximum solenoid field on-axis
S Bdz	integral B dz along axis
U	total stored energy in the magnet configuration

4. Save parameters

This command is used to save the parameters for the current design.



Besides the name of the file the user can enter some descriptive information as the title.

This file can also be created offline with a text editor. The format of the file is:

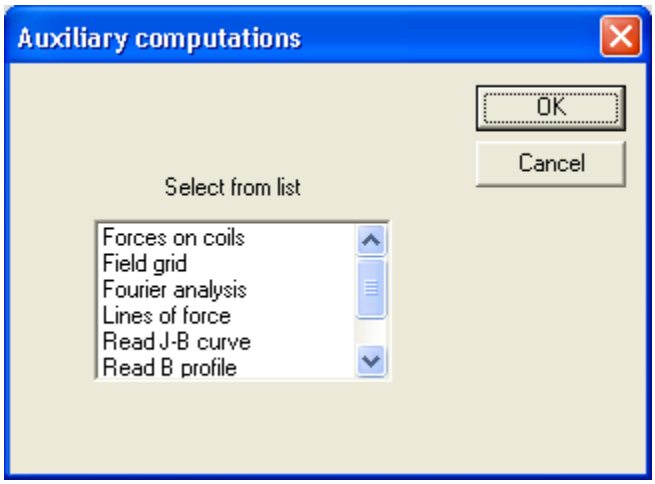
```
Title                    (a80)
zmin  zmax               (R)   lower (upper) axial limit [cm]
ncoils                   (I)  number of coils  {1-32}
For i=1,ncoils
 id  za(i)  La(i)  aa(i)  ta(i)  Ja(i)  ctype(i)   fsc(i)
 where        id      (I)  identifying number for user convenience
              za      (R)  axial position of left edge of coil  [cm]
              La      (R)  axial length of coil  [cm]
              aa      (R)  inner radius of coil  [cm]
              ta      (R)  radial thickness of coil  [cm]
              Ja      (R)  engineering current density  [A/mm^2]
              ctype   (A)  conductor type
                {NbTi, Nb3Sn, BSCCO, YBCOg, YBCOb, Cu, Fe, USER}
              fsc     (R)  current density scaling factor for the material
```

The five defined superconductors {NbTi, Nb3Sn, BSCCO, YBCOg, YBCOb} use reference J-B curves for 4.2 K. YBCOg is YBCO tape in the “good” direction, i.e. with B in the plane of the conductor tape. YBCOb is YBCO tape in the “bad” direction, i.e. with B perpendicular to the plane of the conductor tape. A coil with USER superconductor will use a J-B curve that the user has read in using the AUXILIARY button.

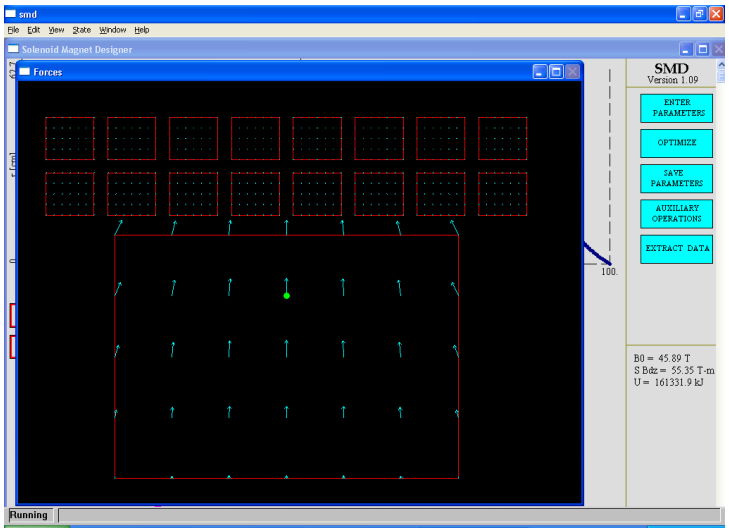
5. Auxiliary Operations

The AUXILIARY OPERATIONS button brings up the choice of the following additional calculations:

Force distribution inside coils
Field grid
Fourier analysis of on-axis field
Lines of force
Read new $J_{eng}(B)$ curve for conductors
Read desired on-axis magnetic field profile
Plot difference between profile and actual B on-axis

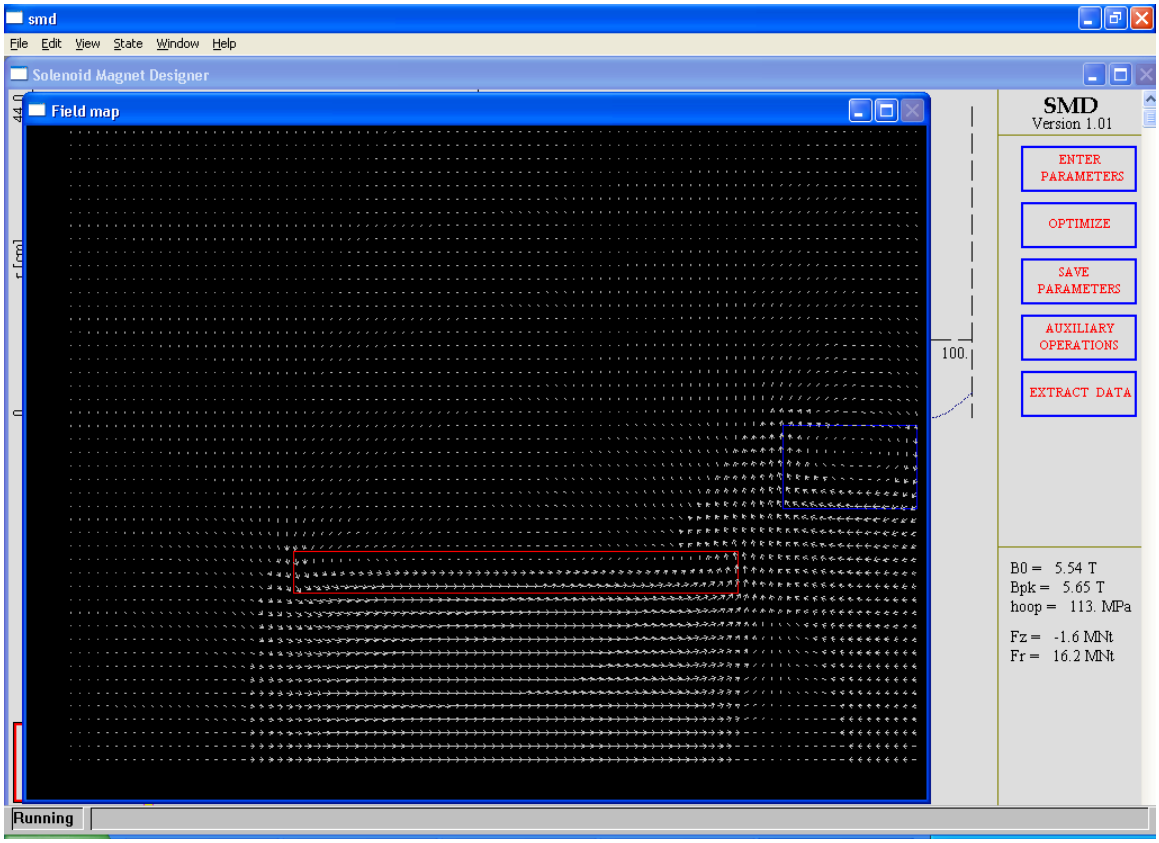


The user must select one of the items in the list and press OK. Here is an example of forces on the coil.



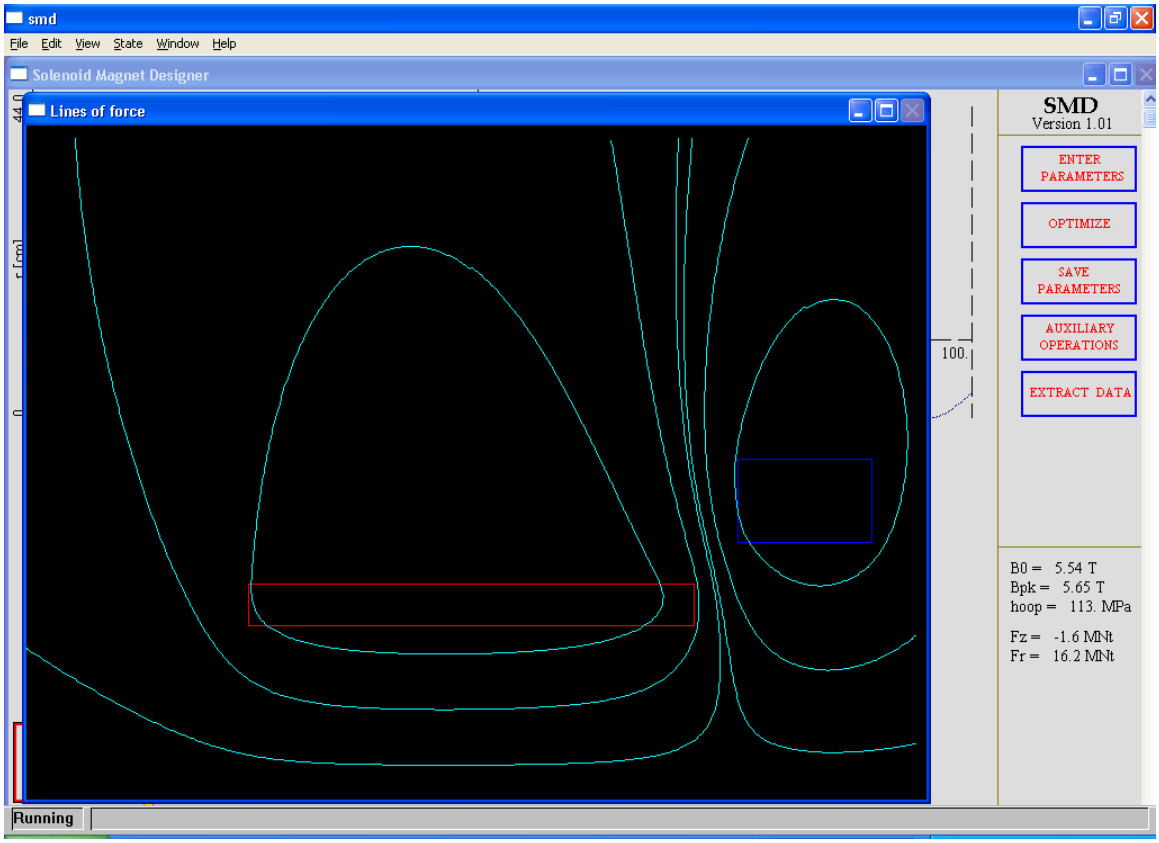
The location of the peak magnitude of the force is shown as a green circle.

Here is an example of a magnetic field grid.



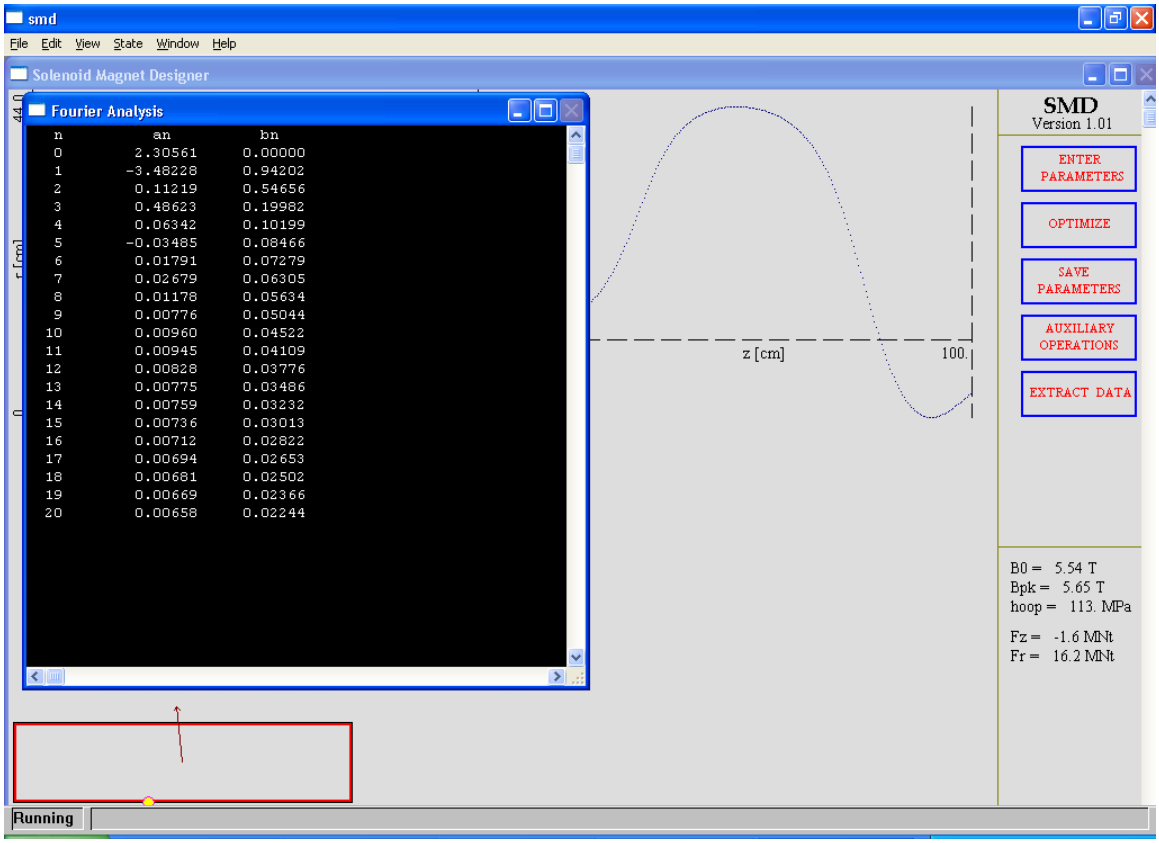
The coil positions are outlined in red and blue.

Here is an example of magnetic lines of force.



The coil positions are outlined in red and blue.

Here is an example of a Fourier analysis of the on-axis magnetic field.



The a_n coefficients are the cosine-like terms, while the b_n coefficients are the sine-like terms.

The format of the external magnetic field profile file is

title	(a80)	
npts	(i)	(1-50)
For i=1, npts		
z [cm]		B [T]

The format of the external J-B curve file is

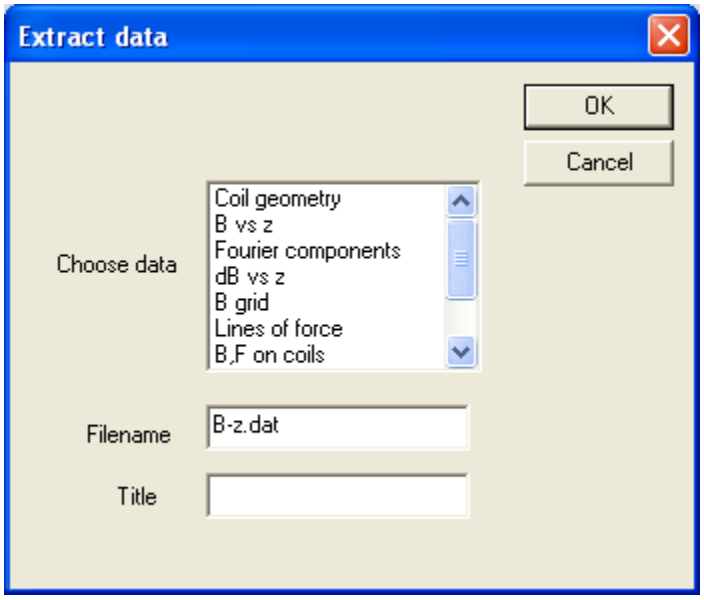
title	(a80)	
npts	(i)	(1-50)
For i=1, npts		
B [T]		J [A/mm^2]

6. Extract Data

EXTRACT DATA creates external ascii files of selected information:

- Coil geometry
- B(z) on-axis
- Field & force on coils
- Map of forces
- Field grid
- Fourier coefficients
- Lines of force
- Field error from desired profile
- Internal $J_C(B)$ data

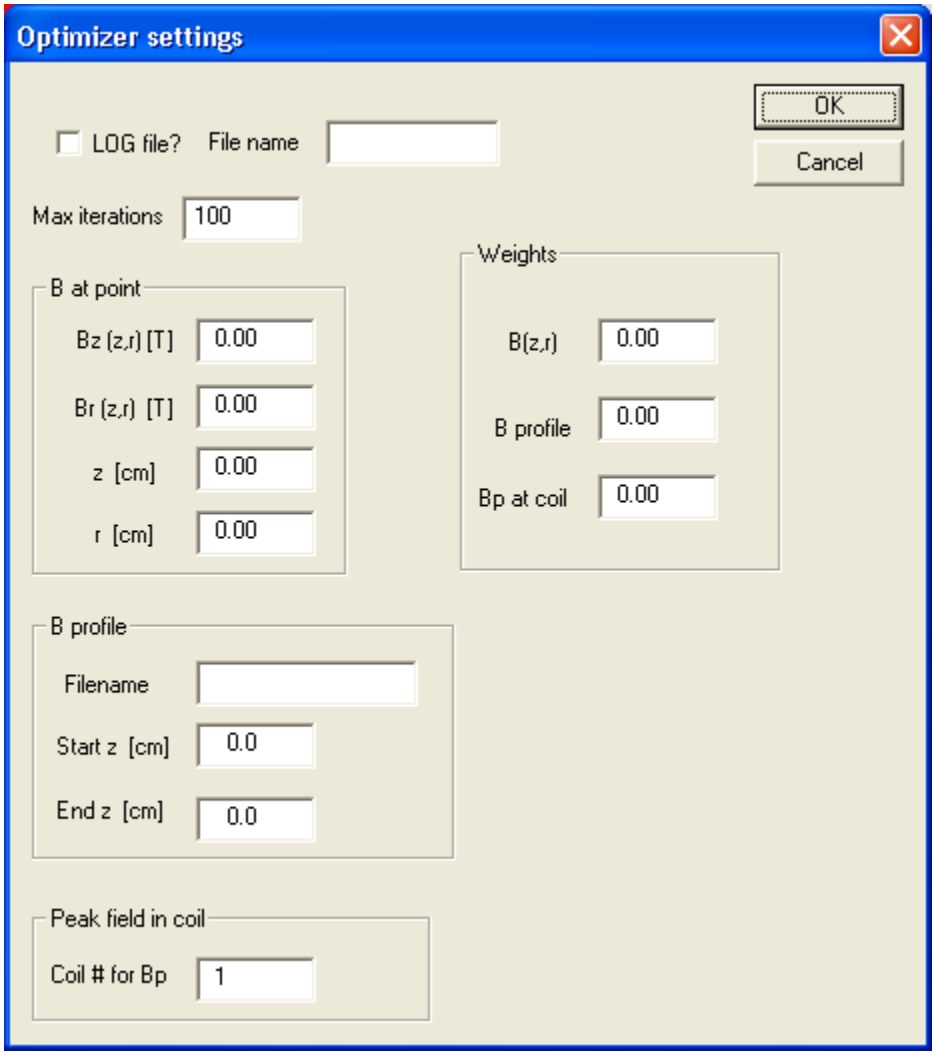
This will bring up the following window.



The user can specify the file name where the data is written and can specify up to 60 characters of "title" information at the head of the file. All available information can be written to a single file by choosing All Data.

7. Optimization

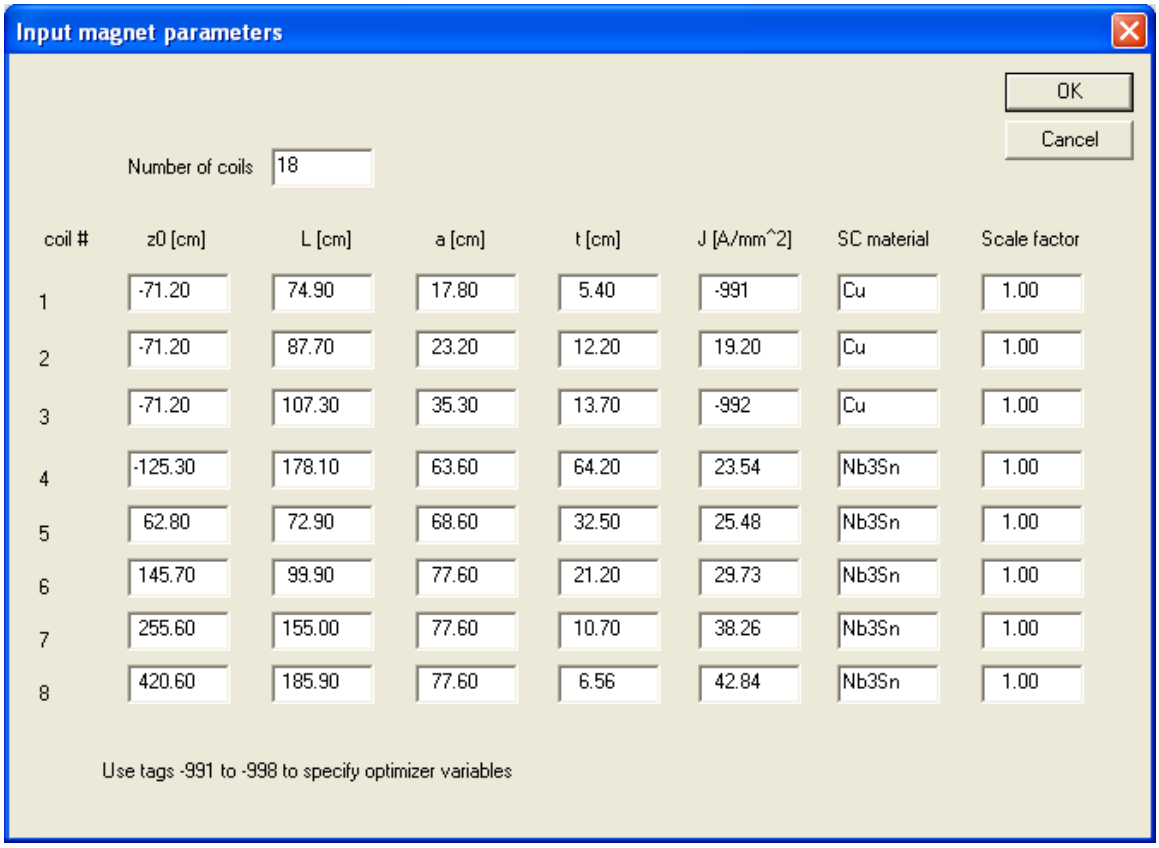
The first window controls some general properties of the optimizer.



The progress of the optimization can be saved in an ascii log file. The optimizer builds the merit function from components. You can require a given magnetic field at a specified (z, r) location. You can require that the magnetic field match a B(z) profile read in from an external file. The optimization is done between the *z* limits given in the boxes. Lastly you can try to minimize the peak field in a given coil. The merit function is controlled by the weights assigned to each of these requirements. At least one weight must be non-zero. The maximum number of iterations roughly controls how long the optimizer will continue.

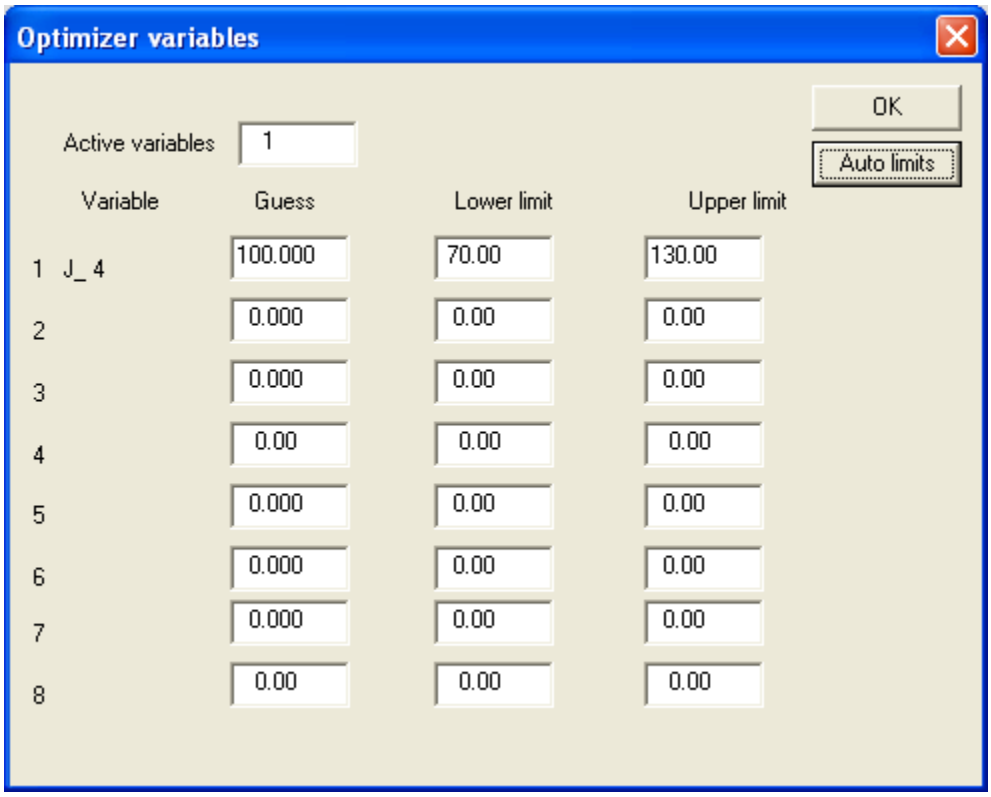
After this window is closed the coil Input parameters windows appear again.

The second Input window is used to specify which parameters will be varied.



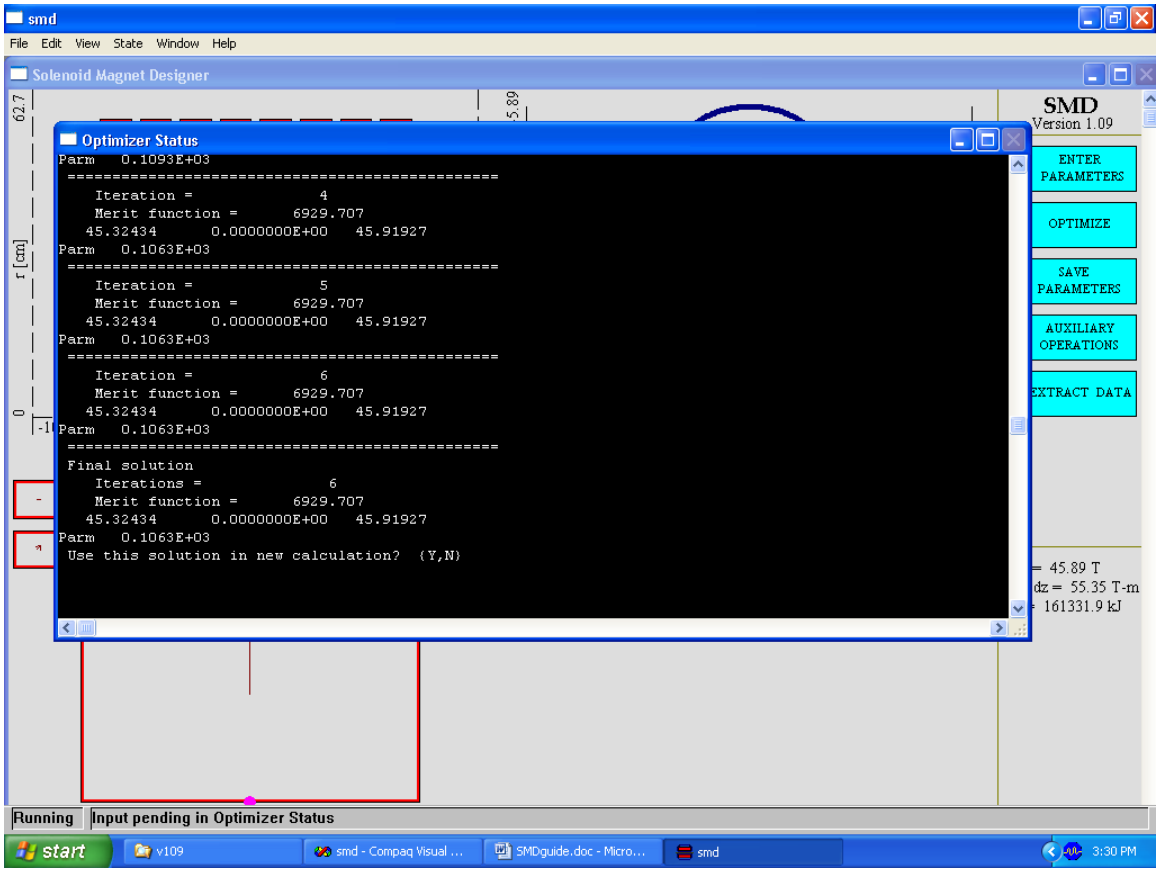
The user enters the tags from -991 to -998 to indicate which parameters to vary in the optimization. The example shown here has two variables: the current densities of the first and third coils.

At this point a second optimizer window appears where the user can specify an initial guess and lower and upper limits for each of the optimizer variables.



The user must enter an initial guess and lower and upper limits for each of the active variables. Clicking on the Auto Limits button will preset the limits automatically to ±30% of the initial value.

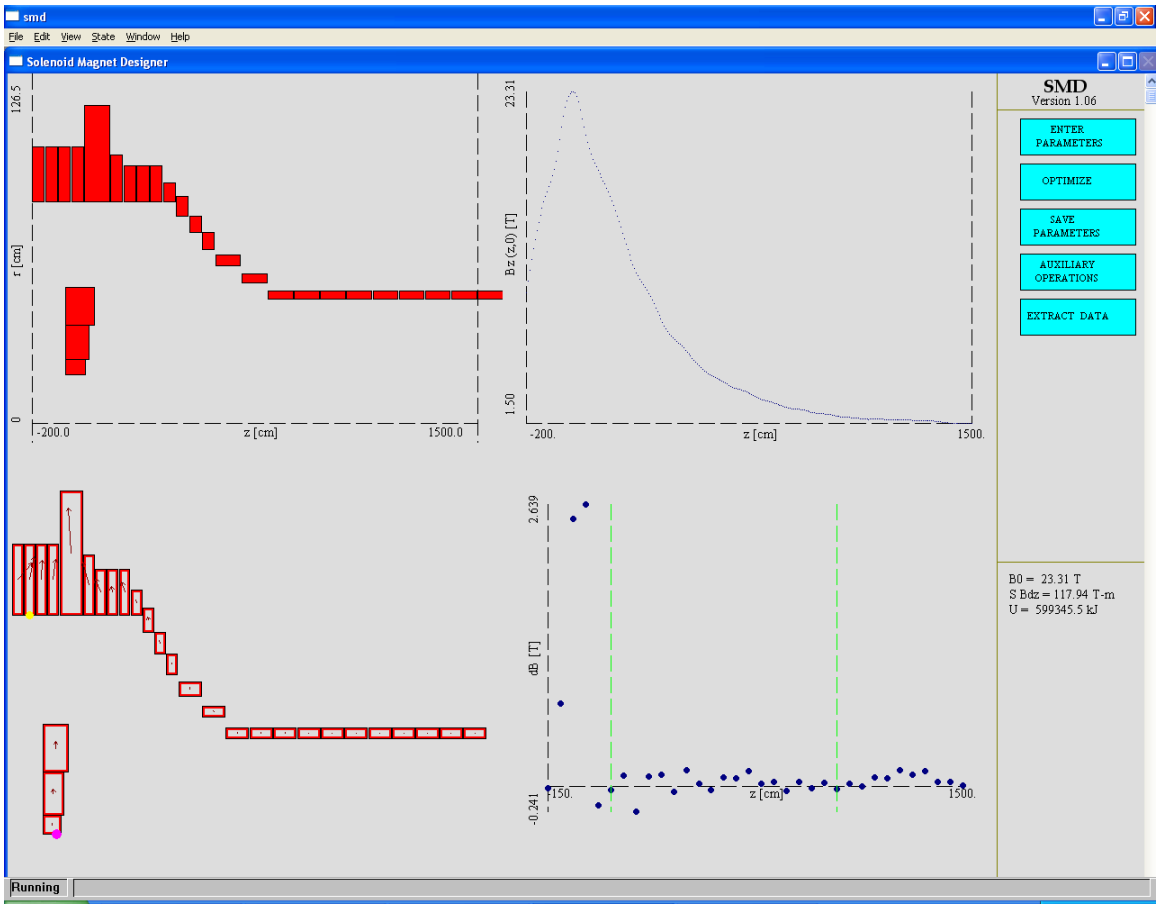
Once the optimization begins the progress is displayed in another window.



The window shows the iteration number, the value of the merit function, and the values of Bz(z,r), Br(z,r) and the peak field in Tesla in the specified coil. The last row shows the values of the selected fit parameters.

At completion the user must type Y to replace the current solution with the optimizer results, or N to ignore it.

If the user is fitting the on-axis field to a desired profile the error field is displayed in the lower right-hand plot.



The vertical green lines show the current z limits for the optimization.